African Educational Research Journal
Vol. 4(3), pp. 109-123, September 2016
ISSN: 2354-2160
Full Length Research Paper

Mathematics anxiety factors as predictors of mathematics self-efficacy and achievement among freshmen science and engineering students

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Accepted 23 August, 2016

ABSTRACT

The main purpose of this study was to determine the direct and indirect effects of mathematics anxiety on achievement in mathematics of first year science and engineering students. Data were obtained from a descriptive survey from 245 (201 male, 44 female) students from five departments of two faculties. Instruments used for data collection were standard scales of mathematics self-efficacy and mathematics anxiety adopted from MSES-R and RMARS for self-efficacy and anxiety, respectively. Factor analysis was used for data reduction and Cronbach's α was obtained to check reliability of each factors. The independent samples t-test was conducted to compare means. Finally, path analyses were done to determine the direct and indirect effects of anxiety factors on mathematics achievement. The results indicate that the anxiety and self-efficacy scales yielded three factors each; the level of prevalence of mathematics anxiety among the gender groups was high for test- and task-related anxieties and moderate for course-related anxiety; no significant gender difference in anxiety was observed; gender difference was significant in only mathematics capability and engagement in mathematics self-efficacy; all the anxiety factors and only two of the self-efficacy factors have significant direct effects on mathematics achievement; and the mathematics test anxiety has significant indirect effect as well through mathematics capability self-efficacy. Recommendations were forwarded that mathematics instructors should support female and mathematics test-anxious students by decreasing mathematics test anxiety and enhancing mathematics self-efficacy to do test. Specifically, teachers can cut students' test anxiety in test taking situations through planned strategies of both teaching as well as preparing students for tests.

Keywords: Mathematics anxiety, mathematics self-efficacy, mathematics achievement, mathematics teaching, factor analysis, path analysis.

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INTRODUCTION

General test anxiety or mathematics anxiety seems to induce some kind of facilitating or impeding effects on engagement in mathematical tasks and mathematics achievement, which therefore needs some intervention. There are cognitive factors as well as affective factors such as motivation, mathematics self-efficacy and mathematics anxiety that contribute to the difficulty or ease students experience in doing mathematics tests or courses and perform mathematics-related tasks. The moderating or suppressing roles of these factors on engagement in mathematics and mathematics achievement need to be understood well in order to ameliorate their influence in students' learning and achievement of mathematics.

Science and engineering students are expected to have mathematical knowledge and reasoning skills in order to deal with analytical and statistical tasks of their senior year courses as well as their job duties in the world of work. However, freshmen students usually have extensive difficulties in doing the courses and attempting the tasks that employ mathematical and statistical applications (Betz, 1987; Tobias, 1987, 1990, 1995;

Bitner et al., 1994). Improving the mathematics contents we teach only addresses part of the issue at hand. We also need to address affective factors, such as mathematics anxiety. They affect mathematics learning, performance, and interest in pursuing science, technology, engineering and mathematics (STEM) majors and careers (PISA, 2012). Thus, to increase students' interest and engagement in STEM, we have to address their fear of mathematics. The researcher had experienced that even more efficacious students exhibit some anxiety-related difficulties in doing mathematics or related computational courses. Individuals who experience fear and apprehension when faced with the prospect of doing mathematics are said to have "mathematics anxiety" (Richardson and Suinn, 1972).

Mathematics anxiety should be regarded from a larger perspective. It is a complex construct consisting of "affective, behavioral and cognitive responses to a perceived threat to self-esteem which occurs as a response to situations involving mathematics" (Atkinson, 1988). Cemen (1987) defined it as a "state of discomfort created when students are required to perform mathematical tasks", whereas Richardson et al. (1972:551) described it as "feelings of tension and apprehension that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary and academic situations". In fact, mathematics anxiety is more than a dislike toward mathematics. Many people experience a genuine fear of mathematics and become nervous when engaging in mathematical tasks (Maloney et al., 2012; Vinson, 2001), avoid mathematics and mathematics-related professions, severely limiting their future career and earning opportunities (Hembree, 1990; Chipman et al., 1992). The resulting shortage of skilled science, technology, engineering and mathematics (STEM) workers has negative consequences at the national level (Chipman et al., 1992). This is particularly true as our society becomes increasingly dependent upon technology.

Feelings of mathematics anxiety are widespread. For instance, an estimated 25% of 4-year college students and up to 80% of community college students suffer from a moderate to high degree of mathematics anxiety in the US (Beilock and Willingham, 2014). Increased mathematics anxiety is linked to decreased mathematics achievement (Lee, 2009). This decreased mathematics performance is not limited to academic situations but also related to large and detrimental consequences in people's daily lives such as reduced teaching self-efficacy among teachers (Olango and Assefa, 2013; Swars et al., 2006), and impaired financial planning (McKenna and Nickols, 1988).

This article reports the second part of the results of a research project on effects of affective variables and mathematics achievement conducted in an Ethiopian university in late 2013. The first part was reported earlier on the causal relationship between mathematics self-efficacy and attitudes on mathematics achievement among freshmen science and engineering students. This empirical study aimed to assess how mathematics anxiety mediates the influence of the self-efficacy on achievement in the same approach as the first study.

Statement of the problem

Researchers have been familiar with affective variables having long-term effects on the students' learning and achievement. However, mathematics educators have primarily focused on cognitive skills and knowledge paying much less thought to non-cognitive factors such as beliefs, attitudes, anxiety, motivations and feelings (Gal and Ginsberg, 1994). Educational research that target at ameliorating the negative effects of these non-cognitive factors on mathematics teaching and learning are apparently useful.

The recent rapid expansion of basic services has helped Ethiopia in achieving the MDGs as related to gender parity in primary education, reducing child mortality, fighting HIV/AIDS, malaria and access to primary education (FDRE, 2010). Ethiopia still ambitiously aspires to increase the number of graduates in science, technology, engineering and mathematics fields in order to create critical task force to uphold its ongoing second growth and transformation plan (GTP II) (FDRE, 2015). Investing in development of, specially, high level manpower is a key to long-term growth and transformation. Nevertheless, it is not producing enough and quality careerists in these fields to work in the increasingly diversified ongoing industrial conversion process of the country.

Current initiatives of popularizing science and technology and the role of mathematics in creating critical scientists and technologists largely ignore the widespread phenomenon of mathematics anxiety that negatively impacts students' interest in and performance of mathematics. On the other hand, research in psychology and education has uncovered techniques that reduce mathematics anxiety and increase mathematics performance (Beilock et al., 2014). Policymakers, curriculum designers, and teachers are urged to consider mathematics anxiety research when designing and implementing programs and instructions aimed at increasing the number of STEM teachers and the number of students interested in STEM careers in the country. Empirical studies that deal with how test and mathematics anxiety may influence students' engagement in mathematical tasks may particularly benefit both mathematics teachers and students.

The purpose of this study is three-fold. First, it intended to explain the variation of mathematics anxiety between gender groups of freshmen science and engineering pre-service students taking calculus course in the context of demanding situations of the first year in college. Second, it was to investigate the extent to which mathematics anxiety directly or indirectly suppresses or facilitates the relationship of mathematics self-efficacy and mathematics achievement. Thirdly, the study also aimed to gain greater understanding of the nature and structure of mathematics anxiety subscales using local student data since the acquisition of mathematics skills and level of mathematics anxiety may vary across cultures (Stevenson et al., 1986). For example, according to a comparative study based on Program of International Student Assessment (PISA) 2003 data (Xin, 2010), which examined the role of classroom assessment and its relationships to student characteristics and mathematics performance, school assessment practices correlated to student achievement differently and interacted differently with individual student characteristics among the three countries: USA, Canada and Finland. This suggested a description of the unique role of assessment practices in mathematics performances in different countries.

Research questions

The study attempted to answer the following basic research questions:

1. What are the factor structures of mathematics anxiety as depicted by the present data?
2. What is the prevalence of mathematics anxiety among the gender groups?
3. To what extent are mathematics anxiety variables correlated with mathematics achievement and self-efficacy variables of first year science and engineering students?
4. Are there direct and indirect effects of gender and mathematics anxiety on student mathematics achievement?

Theoretical framework

The formation of personal capability of an individual by himself, and the attribution of success or failure, depends among other things on external factors taking place in his/her close environment, as well as on internal factors depending on him/herself. To explain the achievements in mathematics as an index for success, environmental factors- class climate in a certain context or the subject of mathematics, as well as, internal factors- mathematics self-efficacy, mathematics anxiety and other affective variables play critical role. Relationships of the affective variables with mathematics achievement were reported at different levels and in different contexts. For example, anxiety- achievement relationships were accounted by Fiore (1999), Pries and Biggs (2001), Ashcraft (2002), Ma and Jiangmin (2004), Ashcraft and Krause (2007), and others (Zedan and Bitar, 2014; Strawderman, 2010; Zopp, 1999; Ma, 1999; Wu et al., 2012; Jackson and Leffingwell, 1999; Hembree, 1990). These relationships and other related literature were reviewed subsequently in order to draw a conceptual framework for the study.

Mathematics anxiety

Mathematics anxiety started with the investigations of Dreger and Aiken (1957:344) who defined it as "the presence of a syndrome of emotional reactions to arithmetic and mathematics". They introduced mathematics anxiety as a new term to describe students' attitudinal difficulties with mathematics. Tobias and Weissbrod (1980) defined mathematics anxiety as the panic, helplessness, paralysis, and mental disorganization that arises among some people when they are required to solve a mathematical problem. It is both an emotional and cognitive dread of mathematics. While some anxiety can be motivating or even exciting, too much anxiety can debilitate, that is, “the brain’s normal processing mechanisms begin to change by narrowing perceptions, inhibiting short term memory and behaving in more primal reactions” (McKee 2002:2).

Pries and Biggs (2001) describe a cycle of mathematics avoidance in four phases. In phase one the person experiences negative reactions to mathematics situations probably due to past negative experiences with mathematics. In phase two the person avoids mathematics situations. This avoidance leads to phase three, poor mathematics preparation, which leads to phase four, poor mathematics performance. This generates more negative experiences with mathematics and brings us back to phase one. This cycle can repeat so often that the mathematics anxious person becomes convinced he/she cannot do mathematics and the cycle is rarely broken. In connection to this, Arem (2003) associates a lot of mathematics anxiety with mathematics test anxiety, which she says is three-fold: Poor test preparation, poor test-taking strategies and psychological pressures. It is exacerbated by poor health habits, especially diet and sleep.

Some more biological studies done on mathematics anxiety (Hopko et al., 1998:344) found that “mathematics-anxious individuals have a deficient inhibition mechanism whereby working memory resources are consumed by task-irrelevant distracters. Consequently, the explicit memory performance becomes poorer for high-anxious individuals”. They also found no relationship between competence and mathematics anxiety. In a similar study, Ashcraft and Kirk (2001:236) found that anxiety reaction involves attention to or preoccupation with intrusive thoughts or worry. This means that students, who do poorly on an exam claim that they become confused, are unable to focus on the task at hand, or keep thinking about how poor they are at mathematics. Similar reports were also made by others (Justicia-Galiano et al., 2016;

Ramirez et al., 2016) concerning cognitive mechanisms and emotional abilities that high-anxiety individuals of all ages experience.

Motivational, intellectual and emotional domains of mathematics anxiety

Expressively, there appear to be three major domains or dimensions which are involved with the development of mathematics anxiety, namely, social/motivational, intellectual/educational and psychological/emotional domains (Strawderman, 2010). There is naturally some overlap between and among them and their boundaries are not well defined. Coupled with each domain is a continuum with extremes on which any given student at any particular time may fall.

The social/motivational domain includes those forces that act upon a person through the agencies of family, friends, and society as a whole. The continuum associated with this domain is *behavior* because although choices are influenced by others, they are ultimately made by the individual. The behavior continuum has avoidance and pursuit as its opposite extremes. These behaviors are logical consequences of the value placed on mathematics, which is influenced by the attitudes of significant others and by society in general (ibid).

The intellectual/educational domain is characterized by those influences that are cognitive in nature. Specifically, they include but are not limited to, the knowledge and skills an individual has and or is expected to acquire and his/her perception of success or failure in them. Although others may "grade" an individual’s performance in this domain, people form their own evaluations of their performance in this area. The continuum associated with this domain is *achievement*, where individual perception is paramount. Failure and success are the extremes of the achievement continuum, and are the subjective evaluations regarding one’s acquisition or use of mathematics skill and concepts (ibid).

The psychological/emotional domain is actually shaped by the affective faculties. It is largely comprised of the individual’s emotional history, reactions to stimuli and arousal states. Hence the continuum coupled with this domain is *feelings* with the extreme ends revealed as anxiety and confidence. The three domains discussed above are theorized to interact in a reinforcing fashion with avoidance behavior, failure in achievement and anxiety feeling (negative cycle) at one end and pursuit behavior, success in achievement and confidence feeling (positive cycle) on the other (ibid). It is apparently the parents’ and instructors’ role to lessen the negative cycle and build on the positive cycle in this reinforcing cycles of interaction.

Mathematics anxiety causes students to avoid mathematics, mathematics classes, and mathematics-related careers (Hembree, 1990), and this avoidance undoubtedly impairs mathematics achievement. As such, students can enter into a vicious cycle in which their anxiety causes them to perform worse in mathematics, and, as a result, they avoid mathematics and opportunities to improve their skills. It is thus important to note that disruption of working memory processes is not the only link between mathematics anxiety and poor mathematics performance. Students who are struggling with mathematics anxiety have little confidence in their mathematical ability, which in turn can negatively affect the actual performance in a math class. They also tend to take the minimum number of required mathematics subjects. This tendency greatly limits their career options after graduation. This is unfortunate especially as society becomes more reliant on mathematical literacy.

Mathematics self-efficacy and anxiety in their relation to achievement

Self-efficacy is one of the cognitive concepts from the field of social learning (Bandura, 1997), which can be connected to the classroom climate prevailing in the educational environment. Mathematics self-efficacy is individual’s judgment of his capabilities to solve specific mathematics problems, perform mathematics related tasks and succeed in mathematics-related courses (Phan and Walker, 2000a, b; Betz and Hackett, 1983; Randhawa et al., 1993). This definition of mathematics self-efficacy was used in this study since it suggests specificity and direction to earlier global assessment of mathematics self-efficacy. Using path analysis, Phan and Walker (2000a, 2000b) investigated the predicting and mediational role of mathematics self-efficacy and found that students' mathematics self-efficacy made an independent contribution to the prediction of their performance in mathematics problem-solving when other motivational variables were controlled. Mathematics self-efficacy mediated further the effects from multiple sources of self-efficacy information onto performance in mathematics problem-solving as reported by other researchers as well (Pajares and Kranzler, 1995; Pajares and Miller, 1994).

An extensive literature has been summarized on the personal and educational consequences of mathematics anxiety (Hembree, 1990). Highly mathematics -anxious individuals are characterized by a strong tendency to *avoid* mathematics, which ultimately undercuts their mathematics competence and forecloses important career paths. Mathematics anxiety is a reaction or phobia (Faust, 1992), with both immediate cognitive and long-term educational implications. Turner et al. (2002) hinted the patterns of student avoidance (e.g., not being engaged or seeking assistance) might have resulted from highly demanding teachers for correctness and not providing any cognitive or motivational support during lessons. Highly math-anxious people also espouse negative attitudes toward mathematics, and hold negative self-perceptions about their mathematics abilities. The correlations between mathematics anxiety and variables such as motivation and self-confidence in mathematics are strongly negative, ranging between -.47 and -.82 (Ashcraft, 2002).

Mathematics anxiety disrupts cognitive processing by compromising ongoing activity in working memory. The investigations whether mathematics anxiety has a measurable on-line effect on cognitive processing, that is, whether it actually influences mental processing during problem solving were done earlier (Ashcraft and Faust, 1994; Faust et al., 1996; Ashcraft, 2002). Results consistent with Eysenck and Calvo's (1992) model of general anxiety effects, called processing efficiency theory were found. In this theory, general anxiety is conjectured to disrupt ongoing working memory processes because anxious individuals devote attention to their intrusive thoughts and worries, rather than the task at hand. In the case of mathematics anxiety, such intrusive thoughts probably involve preoccupation with one's dislike or fear of mathematics and one's low self-confidence. Consequently, it lowers mathematics performance because paying attention to these thoughts acts like a secondary task, distracting attention from the mathematics task. It follows that cognitive performance is disrupted to the degree that the mathematics task depends on working memory.

Conceptual framework for the study

With the goal of checking the connection between emotions expressed in the learning environment in a class context of the mathematics lesson and its various dimensions of anxiety (task-related teacher-student interactions, test-related difficulties, course-related tensions), and aspects of mathematics self-efficacy beliefs (capability, engagement, and career-related assertiveness) and achievements in mathematics, the researcher draws the following conceptual framework to guide this study (Figure 1).

The particular interest in this study was to estimate the degree to which mathematics self-efficacy mediated mathematic anxiety in its influence on achievements in mathematics. Social science literature on academic participation suggests that a mathematical self-efficacy, which is considered as part of a cognitive theory, is explained to a very high extent, by the class climate prevailing in the mathematics lesson and its emotional, cognitive and behavioral dimensions (Zedan and Bitar, 2014). This finding supports the approach seeing cognition as part of emotion. For example, signs of anxiety, fatigue or depression at the time of engagement can lower the feeling of self-efficacy, whilst a feeling of calming, motivation and serenity can increase feeling of self-efficacy (Lent et al., 1999). Zimmerman (2000) stresses that self efficacy is sensitive to the context in which the task is performed. Hence it is possible to conjecture that an anxious class atmosphere can predict self-efficacy directly and mathematics achievement indirectly through the self-efficacy factors.

The anxiety and self-efficacy variables play an important role in the development of motivation of the learner and in the creation of support conditions during the learning. There is a positive correlation between self efficacy and persistence and motivation (Pintrich and Schunk, 2002), between self-efficacy and prior mathematics experience (Pajares and Kranzler, 1995; Pajares and Miller, 1994), and between self-efficacy and mathematics performance (Phan and Walker, 2001, 2002; Pourmoselemi et al., 2013; Olango, 2015; Pajares and Miller, 1995; Schunk, 1991), and between mathematics anxiety and career opportunities (Hembree, 1990). On the other hand, there is a negative correlation between mathematics self-efficacy and mathematics anxiety (Ashcraft, 2002; Turner et al., 2002), and between anxiety and mathematics performance (Ramirez et al., 2016; Eysenck and Calvo, 1992).

This study therefore seeks to compare between the power of creation of self-efficacy and the achievements in mathematics by contrast to the power of prediction of their anxiety in the classroom climate of the achievements in mathematics. The study proposes this model for explanation of the achievements in mathematics in which the variable of mathematics self-efficacy served as a mediating variable between mathematics anxiety (that is, in the mathematics tests, mathematical tasks, and mathematics courses) and achievements in this subject.

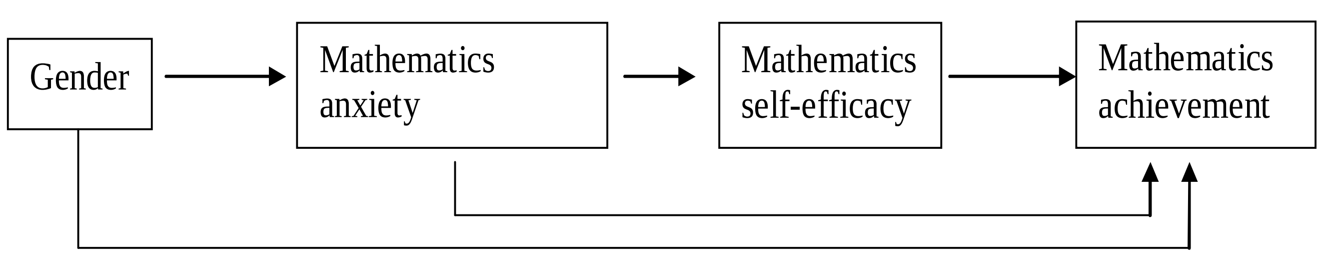

Figure 1. Conceptual framework of the study.

METHODOLOGY

Subjects

The study population was the freshman students of natural science and technology faculties of Hawassa University, Ethiopia, enrolled for three year in science and five year in engineering BSc degree programs in 2013. It was estimated 1250 (approximately 30 per cent female).

Samples

Out of the population above, 274 (214 male, 60 female, nearly 22%) were included in the sample of the study using stratified random sampling. The stratifying variables were gender and department in each faculty. The sampling process observed the principle of proportionality to population size in each department. Comparable sample sizes (53, 54, 57, 52 and 58) were taken from each of the five departments of the study, namely Physics, Mathematics, Computers Science, Electrical engineering, and Civil and Urban Engineering, respectively. Part of the data from this sample was used last December for a similar study conducted by the author.

Instruments

This study looked into co-relational and predictive relationships between the study variables: mathematics self-efficacy, mathematics anxiety, and mathematics achievement of freshman students. To measure the mathematics self-efficacy of students, the researcher adopted Mathematics Self-efficacy Scale-Revised (MSES-R) developed by Betz and Hackett (1986), which was intentionally devised to assess mathematics self-efficacy of college students. The instrument has 25 items and three subscales representing three domains of mathematics-related behavior. The nature and structure of this instrument described in the report of Olango (2015).

The adopted form of the Revised Mathematics Anxiety Rating Scale (RMARS: Alexander and Martray, 1989) was used to measure the students' mathematics anxiety. This scale was abbreviated from the original 98-item instrument (MARS: Richardson et al., 1972), which was too long for administration. It was extensively used (Zettle and Raines, 2000; Plake and Parker, 1982; Levitt and Hutton, 1984; Kazelskis, 1998; Suinn and Winston, 2003; Hopko, 2003). There were only 15 items in this shorter scale and the three factors extracted by Alexander and Martray were expected. Both self-efficacy and anxiety instruments presented students with 5-point Likert type scale, with 1 to 5 for the students to indicate whether they strongly agree=5, agree=4, undecided=3, disagree=2, or strongly disagree=1.

The freshman science and technology students take two Applied Mathematics courses in their first year of college education. These are Calculus I and Calculus II the contents of which cover all major calculus topics. The first course is introductory calculus, significant portion of which is a continuation of what the students actually took in their preparatory school years. The second introduces more or less advanced topics with a more rigorous level of treatment. In both semesters many students exhibit stress and anxiety in performing mathematics problems and mathematics-related tasks. In order to determine the predictive roles of the various affective variables of the study on mathematics achievement, the researcher used the final scores in these courses from the student records offices of the respective departments.

Procedures of data collection

The two instruments on self-efficacy and anxiety were pilot tested in three other departments before final administration using feedbacks from 45 students, 15 from each department. Internal consistency reliability was successfully checked. Besides, two professors of psychometrics reviewed the items in the instruments for clarity of terms, potential bias due to cultural context, and for construct validity.

Technical assistants took part in coordinating the process of final data collection after they were given strict training and orientation about the data collection. These assistants from each faculty/college distributed the instruments in their respective faculty/ college and collect the filled ones. This final administration of the instruments was done in each department under close follow-up of the researcher in collaboration with the department heads to ensure collecting independent responses. Ethical issues- use of subjects' time, confidentiality, privacy right of subjects, and informed consent- were carefully assured.

Methods of analysis

Both descriptive and inferential statistical methods were used to analyze the data. Means and SD were obtained to determine the levels of the study variables. Correlations of the different variables were computed by way of preparation for determining effects of the affective variables on student achievement. Factor analysis was conducted to identify the dimensions of predictor variables and later main analysis was path analysis based on the main factors of each study variable thus identified. The path analysis traced the amount of direct and indirect effects of efficacy on achievement mediating between mathematics anxiety and achievement.

RESULTS AND DISCUSSION

The efforts of this part were to check the construct validity of mathematics anxiety scale adopted for this research, to determine the level mathematics anxiety among the study groups, and to establish direct and indirect effects of the variables on mathematics performance. The validity of mathematics self-efficacy has been verified in Olango (2015) for the data. The response rates of the sample groups fell between 73.59 and 98.11%, the overall response rate being 89.42%, which can be considered as fairly high. Twenty nine cases were discarded because they were either not returned or inappropriately filled. The data obtained from mathematics self-efficacy and anxiety scales as well as students' mathematics performance evaluation were statistically analyzed and results are presented in tables. The discussion of the results is integrated into the reports each set of data.

Factor structures of the mathematics anxiety variables

One of the study objectives is to analyze the factor structure of the mathematics anxiety scale based on current data. Students were actually asked to rate a 5-point Likert type scale regarding anxiety potentially exhibited in mathematics class triggering difficulties. The responses were used for factor analysis to determine the

Table 1. Means, standard deviations, reliabilities, and percentage of explained variances.

Parameter	No. of items	Scale mean	Item mean	Item SD	Cronbach alpha	% of explained variance	Factorability statistics
MA		**70.76**		**13.35**			
MSE	**25**	**84.08**	**3.36**	**8.80**	**.80**	**43.84**	**KMO = .854**
MCSE	13	45.55	3.50	.56	.84	18.17	Chi-sq = 3360,
EMSE	6	24.77	4.13	.68	.86	15.76	df = 780, p<.01
CRMSE	6	13.76	2.29	.61	.79	9.91	Anti-image diag >.70
MARS	**15**	**60.85**	**4.06**	**5.58**	**.78**	**40.10**	**KMO = .75**
MTA	8	35.04	4.38	.61	.86	18.40	Chi-sq = 3360,
MTRA	4	15.40	3.85	.62	.76	11.95	df = 780, p < .01
MCRA	3	10.41	3.47	.58	.72	9.75	Anti-image diag > .70

MARS = Mathematics anxiety rating scale, MTA = Mathematics test anxiety, MTRA = Mathematical task-related anxiety, MCRA = Mathematical course-related anxiety, MSE = Mathematics self-efficacy scale, MCSE = Mathematics capability self-efficacy, EMSE = Engagement in mathematics self-efficacy, CRMSE = Career-related mathematics self-efficacy; Gender: Male = 1, Female = 2.

subscales of mathematics anxiety. The results are presented in Table 1. In the same table results pertaining to self-efficacy scale and mathematics achievement were exhibited again for fresh look at the levels of variables based on the data.

First, the factorability of the 25 MSES-R items and 15 RMARS items was examined separately. In each case, the inter-item correlation coefficients for each subscale were at least .34; the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was .85 and .75 respectively, above the recommended value of .6; the Bartlett's test of sphericity gave (Chi-sq = 3360, df = 780, p < .01) indicating that the correlation matrix among the items was not an identity matrix; all the initial communalities were larger than .66; and all the extracted communalities were larger than .69, indicating that shared variation among the collection of items was at a good level for factor analysis (Tabachnick and Fidell, 2013). These results (Table 1) led the researcher to consider the data reduction processes were justified.

Mathematics anxiety subscales

Three factors of RMARS were determined based on data using 15 items. These are: Mathematics test anxiety (MTA-8 items), Numerical task-related anxiety (MTRA-4 items), and Mathematical course-related anxiety (MCRA-3 items). The items consisted of, for example, “Mathematics has been my worst subject.” (Problem-solving item), “My mind goes blank and I am unable to think clearly when working in mathematics.” (Task-related anxiety item), “It would not bother me at all to take more advanced mathematics courses.” (Course-related anxiety item). Reliability estimate for MARS was .78, which is slightly, but acceptably, lower than what is reported in the literature (Alexander and Martray, 1989; Bowd and Brady, 2002). Cronbach alpha for the identified factors above were .86, .76, and .72, respectively. The alpha values ranged between .71 and .87 whereas the corresponding alpha values in the literature fell between .78 and .96 (Moore et al., 1988).

Mathematics self-efficacy subscales

The three factors that MSE scale yielded based on data using 25 items are: Mathematics problem solving capability self-efficacy (MCSE, 13 items), Engagement in mathematical tasks (EMSE, 6 items), and Career-related Mathematics self-efficacy (CRSE, 6 items). The items included, for example, “Generally, I am confident in attempting mathematics.” (MCSE item), “I can engage myself with studying mathematics when preparing for its test.” (EMSE item), and “I can use mathematics skills for earning living.” (CRSE item). Reliability estimate for MSE was .82. Moreover, the data confirm earlier studies or the results of developers of the scales (Betz and Hackett, 1986; Richardson et al., 1972; Zettle and Raines, 2000; Pajares and Miller, 1995).

The prevalence of mathematics anxiety

The preceding parts showed the factor structures of each of the anxiety and self-efficacy variables using the data. The study also aimed to show the prevalence of mathematics anxiety among the different groups of freshman science and technology students at Hawassa University. Table 1 shows the summated score means, item means, scale and item standard deviations, reliabilities, and percentage of explained variances of both anxiety and self-efficacy subscales under each scale.

For the ease of interpretation, item mean value 1 through 1.50 is considered very low; 1.50 through 2.50 is low; 2.50 through 3.50 is moderate; 3.50 through 4.50 is high; and 4.50 through 5 is very high prevalence in each scale and subscale. The percentage of variance of mathematics anxiety explained by MARS in this study is 40.10. It confirms the results of studies of RMARS (Alexander and Martray, 1989; Bowd and Brady, 2002) using undergraduate students' data which found that the three subscales were evident explaining 31 to 73% of total variance. Accordingly, typical prevalence of the anxiety and self-efficacy variables and mathematics performance for the overall data is presented in Table 1. We can generally observe that the mathematics self-efficacy are moderate (MSE mean = 3.36), whereas mathematics anxiety is high (MARS mean = 4.06). The item means of the anxiety factors were 4.38, 3.85 and 3.47 for test anxiety, task-related anxiety, and course-related anxiety, respectively. While mathematics test anxiety and task-related anxiety were high (MTA = 4.38, MTRA = 3.85), course-related anxiety was moderate (MCRA = 3.67) among students. We observe that the test anxiety was above the overall anxiety mean score for the data. This indicates that students' are emotionally more anxious to do mathematics tests than to take advanced courses. Their high test anxiety and task-related anxiety may be related to their high engagement in doing exercises (EMSE = 4.13).

The findings were consistent with other results of prevalence of anxiety among students. For example, Pourmoselemi et al. (2013) found that evaluation mathematics anxiety was more than the mean and undergraduate students had higher evaluation mathematics anxiety as compared to total mathematics anxiety and learning mathematics anxiety. In fact we can conclude that the students had at least moderate mathematics anxiety in the classrooms when they were learning mathematics, but the examination situation could create higher mathematics anxiety for them, especially with advanced courses. Earlier study based on large survey of prevalence of mathematics anxiety found that over 25% of 4-year college students and up to 80% of community college students had a moderate to high mathematics anxiety (Jones, 2001; Beilock and Willingham, 2014); people of all races and economic backgrounds fear mathematics (Zaslavsky, 1994); developmental mathematics students and nontraditional students were more mathematics anxious than other college students (Preis and Biggs, 2001); and parents and teachers with mathematics anxiety pass it along to their children or students (Fiore, 1999).

Gender influence on anxiety variables

This study looked into gender difference in mathematics anxiety, self-efficacy and mathematics achievement. It revealed (Table 2) that there is no significant gender difference in mathematics anxiety, whereas there is significant gender difference only in mathematics capability self-efficacy ($t = 2.67$, $p < .05$), in engagement in mathematics self-efficacy ($t = 2.08$, $p < .05$), and in mathematics achievement ($t = 2.84$, $p < .05$). What could be the force behind males outscoring females on freshman mathematics achievement tests? Eccles and Jacobs (1986) argued that standardized performance tests are not true measures of innate mathematical ability due to many factors that can affect performance such as test anxiety, risk-taking preferences, cognitive style, and confidence in one's abilities (p. 369). They contend that "sex differences in mathematical achievement and attitudes are largely because of sex differences in mathematics anxiety, the gender-stereotyped beliefs of parents, especially mothers, and the value students attach to mathematics" (p. 370). However, the insignificant results in the mathematics anxiety in this study and other attitudinal variables (Olango, 2015) might be indicating that more focus should be on building girls' mathematics self-efficacy starting right from lower grades.

Different researchers (Ayotola and Adedeji, 2009; Hyde et al., 1990) reported that mathematics anxiety has significant correlations with student's self-efficacy, gender, and mathematics achievement. Generally, males perform better than females in mathematics achievement, but this difference is not really visible until adolescence (Parajes and Miller, 1994). The difference prevailed when it comes to problem solving (Hyde et al., 1990:300). Interestingly, females' grades tend to be higher than males' grades on teacher reports (Hyde et al., 1990:300). Hackett (1985) confirmed these findings in an independent investigation. It seems that the difference remains contentious calling for research under specific areas of mathematics performance.

Correlations among study variables

This study aimed to investigate the degree of relationship between mathematics performance and the anxiety factors as well as mathematics self-efficacy using current data. Table 3 depicts that mathematics achievement is significantly correlated with mathematics capability self-efficacy ($r = .45$, $p < .01$), with engagement in mathematics self-efficacy ($r = .37$, $p < .01$), and with career-related self-efficacy ($r = .27$, $p < .01$), whereas it is significantly and negatively correlated with mathematics test anxiety ($r = -.29$, $p < .01$) and with mathematics task-related anxiety ($r = -.19$, $p < .05$). However, the research literature reports on Pearson correlations between self-efficacy and academic execution ranging in a range $0.49 < r < 0.70$ (Pajares, 2002), which were much stronger results. A comparative study on assessment use, self-efficacy and mathematics achievement (Xin, 2010) also

Table 2. The t-test summary.

	Male		Female		df	T	Sig.
	M	SD	M	SD			
MA	71.88	12.58	65.66	15.58	243	2.84*	.005
MTA	2.17	.60	2.27	.64	240	-1.01	.312
MTRDA	3.30	.61	3.14	.63	236	1.51	.132
MCRA	4.20	.59	4.17	.55	241	.37	.712
MCSE	3.55	.55	3.29	.58	228	2.67*	.008
EMSE	4.17	.65	3.93	.80	238	2.08*	.038
CRSE	2.67	.60	2.41	.67	239	-1.40	.239

* p < .05, **p < .01; Variable abbreviations are as in Table 1.

Table 3. Correlations of the affective variables and mathematics performance.

		MA	MSE			MARS			Gen
		1	2	3	4	5	6	7	8
1	MA	1	.45**	.37**	.27*	-.29**	-.19*	-	-.18*
2	MCSE		1	.43**	.46**	-.54**	-.28**	-.44**	-.17*
3	EMSE			1	.21*	-.39**	-.33**	-.29**	-.13*
4	CRSE				1	-.55**	-.37**	-.31**	-
5	MTA					1	.19*	.28**	-
6	MTRA						1	.22*	-
7	MCRA							1	
8	Gen								1

Note: Only significant correlations are displayed, * p < .05, **p < .01; Variable abbreviations are as in Table 1; Non-significant coefficients were suppressed in this table.

indicated that student individual characteristics such as gender, family social-cultural status, foreign language spoken at home, effort invested on test, time spent on homework, mathematic self-efficacy and expected education level are similarly related to mathematics performance across different countries.

There is no significant relationship between achievement and course-related anxiety ($r = -.04$, $p > .05$) and weak significant relationship between achievement and gender ($r = -.18$, $p < .05$). This indicates that mathematics self-efficacy factors have relatively stronger relationship with achievement than gender and the anxiety factors. On the other hand, all efficacy variables are significantly related with the anxiety variables with negative coefficients ($-.55 < r < -.20$, $p < .01$), with gender ($-.17 < r < -.13$, $p < .05$). It might be through self-efficacy factors that gender and anxiety factors influence students' mathematics achievement.

Research also shows long-established results similar to these findings. A significant weak negative correlation ($r = -0.138$, $p < 0.01$) was found between the gender inequality and mathematics self efficacy; similarly a weak negative correlation ($r = -0.162$, $p < 0.01$) was found between gender and mathematics achievement (Zedan and Bitar, 2014). This means that the more inequality exists in the attitude of the teacher to the students in the mathematics lesson and there exists discrimination on a gender background, the mathematics self-efficacy of the student will be lower, and his/her achievements in mathematics will be lower. A significant weak negative correlation ($r = -.090$, $p < 0.05$) between mathematics anxiety dimension of tension and mathematics self efficacy, and similarly a weak negative correlation ($r = -0.115$, $p < 0.01$) was found between this dimension and educational achievements in mathematics. This means that the more tension exists in the mathematics lesson and in relations between students and teachers in the mathematics lesson, the mathematics self efficacy of the student will be lower, and his/her achievements will decline.

Predictive roles of anxiety and self-efficacy variables in mathematics achievement

How much of the variance in mathematics achievement is directly or indirectly explained by mathematics anxiety and mathematics self-efficacy? To investigate this, a path analysis was employed. It examined the direct and indirect effects of these variables including gender. As a statistical procedure, path analysis is a multiple regression route that looks into causal pathways between variables showing these effects of a variable on a given dependent variable (Pedhazur, 1982; Tabachnick and

Fidller, 2013). It gives estimates of the magnitude and significance of hypothesized causal connections between sets of variables. Its merit is that it shows which variables put forth effects on others, whether these effects are direct or indirect and whether they are false or genuine paths. A direct effect is one between two variables with no intervening variable; indirect effects are those that are mediated through some intermediary variable. This is best illustrated by a path diagram showing exogenous and endogenous variables at work in the analysis (Olango, 2015).

The effect of gender on mathematics performance was known to be mediated by mathematics anxiety variables (Zedan and Bitar, 2014) and by mathematics self-efficacy variables (Parajes and Miller, 1994). The effect of mathematics anxiety is also mediated by students' mathematics self-efficacy beliefs (Zedan et al., 2014). Ashcraft et al. (1998) found that math achievement scores decrease as math anxiety increases, which actually replicated the overall result reported by Hembree (1990). Based on such empirical evidences and the significant correlations between achievement and the motivational variables observed in the data, the following input path diagram (Figure 2) was conceptualized to see the effects. Figure 2 represents the causal connections that are proposed by our hypothesis. The output path diagram (Figure 3), on the other hand, represents the data results.

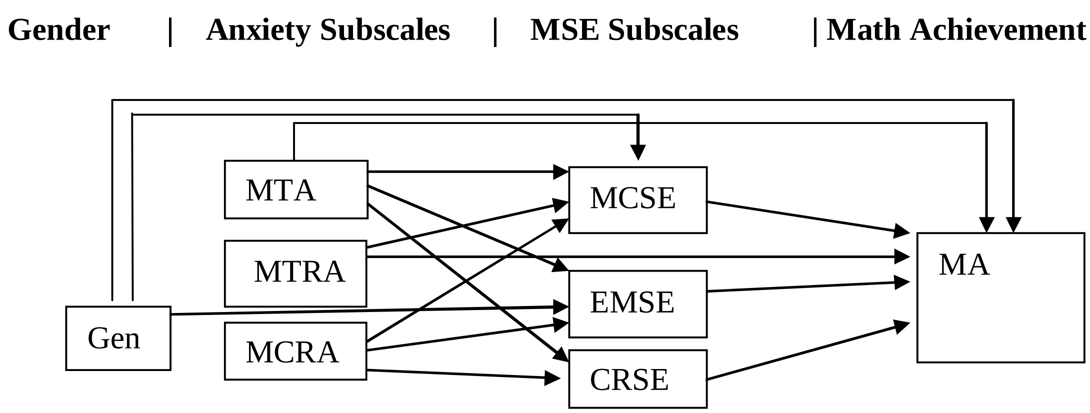

Figure 2. Initial path model: Effects of gender, anxiety and self-efficacy variables on mathematics achievement. Adapted from Olango (2015) and Zedan and Bittar (2014). Note: Variable abbreviations are as under Table 1.

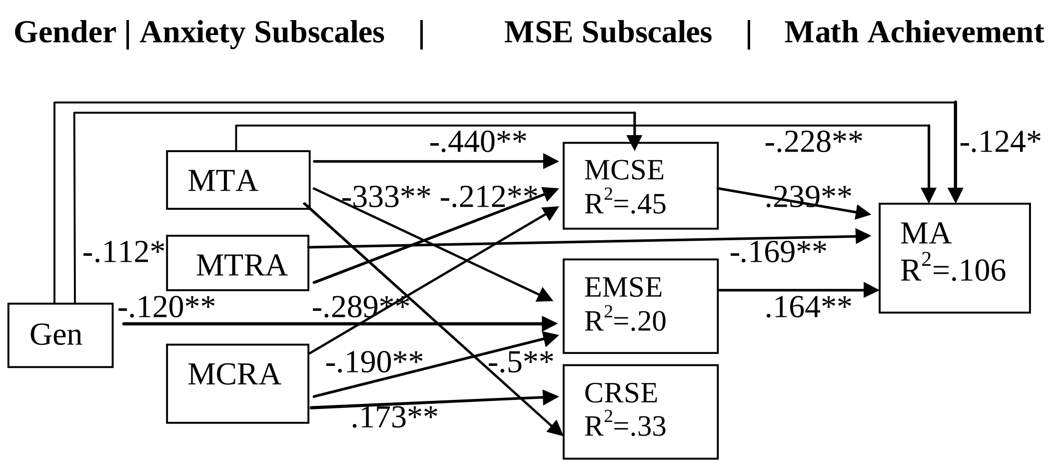

Figure 3. Output path model: Effects of gender, anxiety and self-efficacy variables on mathematics achievement. Adapted from Olango (2015). Note: Variable abbreviations are as under Table 1.

The significant correlations among the study variables (Table 3) suggest which variables could lead to mathematics achievement. Foster et al. (2006) recommended the standard enter selection method as an appropriate entry type in this regression analysis in order to identify significant variance contributors. A strong correlation of independent variable with the dependent variable is usually an indicator of order of entry. Thus, the researcher identified the initial model showing the hypothesized paths leading to endogenous variables (Figure 2). There were four separate regressions run to explain the four endogenous variables in the input model. The first has mathematics achievement as the dependent variable. With betas (βs) representing the computed regression coefficients, the following regression equation stands for the pathway:

$$MA = \beta_1 Gen + \beta_2 MTA + \beta_3 MTRA + \beta_4 MCSE + \beta_5 EMSE + \beta_6 CRSE \quad (1)$$

The regression for MA yielded the following beta values: $\beta_1 = -.124^*$, $\beta_2 = -.228^{**}$, $\beta_3 = -.169^{**}$, $\beta_4 = .239^{**}$, $\beta_5 = .164^{**}$, $\beta_6 = .061$, only four of which were significant contributors to the path. The significant contributors were gender, mathematics test anxiety, mathematics capability self-efficacy and engagement in mathematics self-efficacy in predicting achievement. The non-significant contributors were removed from the output model. The computed R-square was .080 showing that 8.0% of the variation in mathematics achievement is accounted for by this model. The anxiety variables, except test anxiety, did not as such play significant role in predicting achievement in the presence of self-efficacy variables mentioned above; neither does career-related self-efficacy. On the other hand, it is hypothesized that the self-efficacy variables behave as intermediary variables between anxiety variables and achievement, so we next look into the paths leading from anxiety variables to self-efficacy variables.

Thus the second, third and fourth paths were identified from the input model as follows:

$$MCSE = \beta_7 Gen + \beta_8 MTA + \beta_9 MTRA + \beta_{10} MCRA \quad (2)$$

$$EMSE = \beta_{11} Gen + \beta_{12} MTA + \beta_{13} MTRA + \beta_{14} MCRA \quad (3)$$

$$CRSE = \beta_{15} MTA + \beta_{16} MCRA \quad (4)$$

The resulting beta values were: $\beta_7 = -.112^{**}$, $\beta_8 = -.440^{**}$, $\beta_9 = -.212^{**}$, and $\beta_{10} = -.289^{**}$, from the second path; and $\beta_{11} = -.120^{**}$, $\beta_{12} = -.333^{**}$, $\beta_{13} = -.025$, and $\beta_{14} = -.190^{**}$ from the third path; $\beta_{15} = -.5^{**}$, and $\beta_{16} = -.173^{**}$ from fourth path. Inputting the beta values into the path diagram Figure 2 gives us Figure 3. The significant coefficients of the last three paths show that the anxiety factors substantially contribute to the prediction of mathematics self-efficacy thus adding to the prediction of mathematics achievement to a similar extent. This was further indicated by the significant R-square values for the paths were: .445*, .203*, and .332*, respectively. Each indicates the total variance in the respective endogenous variable explained by the path. These values were at least as good as the corresponding values of the models when mathematics attitudes were included instead of mathematics anxiety variables. The results probably point to that both are important variables to forecast mathematics performance.

Findings indicated that gender had significant direct ($\beta = -.124$, $p < .05$) and insignificant indirect effects on mathematics achievement, the indirect effects being through two self-efficacy factors mathematics capability and engagement in mathematics. Except the course-related anxiety, all anxiety and self-efficacy variables in the model had significant direct and total effects ($-.387 < \beta < -.174$, $p < .05$ for anxiety, and $.164 < \beta < 239^*$, $p<.05$ for self-efficacy) on achievement. The test anxiety however had significant indirect effect as well on achievement through mathematics capability self-efficacy (Table 4).

Previous researchers, who have investigated the relationship between mathematics self-efficacy and various mathematics outcomes, similarly reported significant correlations and strong direct effects (Hackett, 1985; Hackett and Bent, 1989; Parajes and Miller, 1994, 1995a, b; Siegel et al., 1986). For example, Hackett and Bent (1989) found that mathematics self-efficacy beliefs were highly predictive of undergraduates' choice of major event when variables such as mathematics aptitude and anxiety were controlled. Parajes and Miller (1994), using path analysis to investigate mathematics problem solving from a social cognitive perspective, also found that self-efficacy with regard to solving mathematics problems was more predictive of performance than were prior determinants such as gender or mathematics background or variables such as mathematics anxiety, mathematics self-concept, and the perceived usefulness of mathematics. Others (Ma, 1997; Ma and Kishor, 1997; Ma and Jiangmin, 2004; Liu and Koirala, 2009), identified that a strong effect of mathematics self-efficacy ($\beta = .36$) on achievement suggesting that in addition to promote students' attitude toward mathematics it is more important to promote their self-efficacy in order to enhance achievement in mathematics.

On the other hand, a meta-analysis (Ma, 1999) based on 26 studies on the relationship between anxiety toward mathematics and mathematics achievement among elementary and high school students showed significant population correlation for the relationship and a series of general linear models indicated that the relationship is consistent in gender groups, grade-level groups, and ethnic groups. Yet, published studies (Eysenck and Calvo, 1992; Pourmoselemi et al., 2013; Ramirez et al., 2016) tend to indicate a significantly smaller magnitude relationship than unpublished studies. There are no significant interaction among key variables such as gender, grade, and ethnicity.

The anxiety variables significantly predicted ($-.440 < \beta < -.212$, $p < .01$) mathematics capability self-efficacy in

Table 4. Direct and Indirect effects of gender and anxiety variables.

Effect	R^2	Direct	Indirect	Total	Error
On Math Achievement					
Of Gender		-.124*	-.046$^{\alpha}$	-.170*	
Of MTA		-.228**	-.159*	-.387**	
Of MTRA	.106*	-.169*	-.051	-.220**	.894
Of MCRA		-	-.069	-.069	
Of MCSE		.239**	-	.239*	
Of EMSE		.164*	-	.164*	
On MCSE					
Of Gen		-.112**	-	-.112**	
Of MTA	.445*	-.440**	-	-.440**	.426
Of MTRA		-.212**	-	-.212**	
Of MCRA		-.289**	-		
On EMSE					
Of Gen		-.120*	-.020	.140*	
Of MTA	.203*	-.194*	-	.194*	.617
Of MTRA		-	-	-	
Of MCRA		-.190**	-		
On CRSE					
Of Gen		-	-	-	
Of MTA	.332*	-.500**	-	-.500**	.504
Of MTRA		-	-	-	
Of MCRA		-.173**		-.173**	

Note: Variable abbreviations are as under Table 1; **p< .01, *p< .05; $^{\alpha}$ combined Indirect effects through MCSE and EMSE.

this study. Particularly, test anxiety significantly predicts not only mathematics capability self-efficacy but also engagement in mathematics self-efficacy. This indicates that reducing test anxiety, which is under teachers' intervention mechanism to boost student efficacy, might enhance students efficacy to be confident of and engaged in doing mathematics and hence to perform better. The current study thus suggests that enhancing self-efficacy by decreasing anxiety may be a good strategy to boost achievement. This converges to the basic recommendation ideas proposed by educators (Bitner et. al., 1994; Frioe, 1999; Jackson and Leffingwell, 1999; Hembree, 1990) and by psychologists (Arem, 2003; Jones, 2001; Tobias, 1995; Eysenck and Calvo, 1992).

Summary of findings

The factor structures of mathematics anxiety scale were found to be acceptably reliable as depicted by the current data. So were those of the self-efficacy scale. The total variance explained in each was over 40% which is quite significant. Three factors were identified for each of these scales in the same way as in the literature. Levels of perceived self-efficacy and anxiety among students by gender were evaluated for the study group. The mathematics capability and engagement in mathematics self-efficacies were high for both sexes, whereas course-related self-efficacy is at moderate level for the group. In the case of anxiety factors, test- and task-related anxieties were high among students whereas course-related anxiety was moderate.

Mathematics achievement is significantly correlated with mathematics capability self-efficacy, with engagement in mathematics self-efficacy, and to lower degree with career-related self-efficacy, whereas it is significantly and negatively correlated only with mathematics test anxiety and with mathematics task-related anxiety. However, the research reports in literature showed stronger correlations between self efficacy and academic performance.

There is weakly significant relationship between achievement and gender and no significant relationship between achievement and course-related anxiety. On the other hand, all efficacy variables are significantly related with the anxiety variables and gender with negative coefficients. It was also observed that mathematics self-efficacy factors have relatively stronger relationship with achievement than gender and the anxiety factors.

Findings also showed that gender had significant direct and insignificant indirect effects on mathematics achievement through only two self-efficacy factors mathematics, capability and engagement in mathematics self-efficacy. Except the course-related anxiety, all anxiety and self-efficacy factors contributed significant direct and total effects on achievement. The test anxiety, however, had significant indirect effect as well on achievement through mathematics capability self-efficacy. An interesting part of this finding is that mathematics capability self-efficacy, which is considered as part of a cognitive theory, is explained to a high extent, by mathematics test anxiety prevailing in the mathematics class and its emotional, cognitive and behavioral dimensions.

In sum, the findings point to mathematics self-efficacy being the best predictor of mathematics achievement followed by anxiety and gender. The need for educational stakeholders and curriculum planners to design programs that will enhance mathematics self-efficacy of students is evident. It will benefit students in doing mathematics and in pursuing science and engineering careers. One of the major strategies to enhance mathematics self-efficacy achievement is by reducing anxiety creating classroom climate, which is teachers' responsibility.

CONCLUSIONS

Based on data the following conclusions were made:

1. The anxiety scale RMARS yielded three factors, namely, mathematics test anxiety, mathematics task-related anxiety and mathematics course-related anxiety.
2. Regarding the level of prevalence of mathematics anxiety among the gender groups, test- and task-related anxieties were high among both male and female students whereas course-related anxiety was moderate among them. No significant gender difference in anxiety was observed between males and females.
3. Gender differences were significant in only mathematics capability and engagement self-efficacy factors and in mathematics achievement.
4. Mathematics capability self-efficacy and engagement in mathematics self-efficacy are significantly and positively correlated with mathematics achievement, whereas mathematics test anxiety and mathematics task-related anxiety are significantly and negatively correlated only with mathematics achievement.
5. While all the anxiety factors and only two of the self-efficacy factors have significant direct effects on mathematics achievement, the mathematics test anxiety has significant indirect effect as well through mathematics capability self-efficacy.

RECOMMENDATIONS

The study extends the following recommendations:

1. Since the study variables are behavioral constructs, it is desirable to re-examine the factor structures of mathematics anxiety and mathematics self-efficacy scales with other data.
2. Significant indirect effects, through mathematics capability self-efficacy, of gender and mathematics test anxiety might be alerting educators to support female and mathematics test-anxious students by decreasing test anxiety and enhancing self-efficacy in test taking situations. Specifically, teachers can plan strategies that avoid anxiety provoking classroom climate that influences the behavior of the students and their level of knowledge, achievement motivation, self image, positions towards the subject, and towards the class.
3. School leaders, science and engineering teachers and the general public should extend views that popularize mathematics as a subject, rather than stigmatize it, painting it as a difficult domain to try.
4. Mathematics teachers and parents are entrusted with the natural and professional responsibilities to support their students and children to overcome the anxiety towards mathematics, to build the self-efficacy in mathematics, and also to take care not to pass any high-anxiety or low-efficacy syndrome they themselves might possess to their children.

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Citation: Olango, M. (2016). Mathematics anxiety factors as predictors of mathematics self-efficacy and achievement among freshmen science and engineering students. African Educational Research Journal, 4(3): 109-123.